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CLINICAL ARTICLE

Functional outcome analysis: instrumented posterior lumbar interbody fusion for degenerative lumbar scoliosis

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Abstract
Purpose Although instrumented posterior lumbar interbody fusion (PLIF) has been becoming a popular and effective method for treating degenerative lumbar scoliosis, the clinical outcome is rarely reported. We retrospectively evaluated the clinical and radiographic outcomes in patients with degenerative lumbar scoliosis after instrumented PLIF.
Materials and methods A total of 58 patient's clinical characteristics had been reviewed retrospectively including clinical presentations, preoperative medical comorbidities, intraoperative status, and postoperative status. Oswestry disability index (ODI), visual analog scale (VAS), and patient satisfaction were evaluated before surgery and last follow-up period. The relationship between the difference of radiographic parameter and functional outcome was evaluated.
Results Functional outcomes including ODI scores and VAS were significantly improved at the last visit. The ODI was 28.1±8.0 before surgery and 12.2±8.8 at the last visit. VAS was 7.4±2.0 before surgery and 2.4±2.0 at the last visit. Patient satisfaction was 72% at the last visit. ODI was significantly related to postoperative radiographic parameters including Cobb's angle ($p<0.001$), L4 inclination ($p=0.011$), coronal balance ($p=0.007$), lateral vertebral translation ($p<0.001$), Nash–Moe grade ($p=0.033$), Nash–Moe degree ($p=0.025$), and sagittal balance ($p=0.041$) Using multiple regression analysis, ODI was significantly related to female gender, number of levels fixed, coronal balance, lateral vertebral translation, and Nash–Moe degree. The was no significant correlation between postoperative radiographic parameters and pain (VAS). Only lateral vertebral translation demonstrated a significant correlation in multiple regression analysis.
Conclusions Based on the VAS and ODI instrument, our studies demonstrated that instrumented PLIF for adult degenerative lumbar scoliosis can achieve a high rate of patient satisfaction and improvement in radiographic and clinical outcomes at a minimum of 2 years of follow-up.

Keywords Degenerative lumbar scoliosis · Posterior lumbar interbody fusion · Functional outcome

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Introduction

Degenerative lumbar scoliosis had an increased incidence in the aged population, and a rising number of elderly patients suffering from degenerative lumbar scoliosis may be eligible for surgical intervention [58]. Although the etiology of degenerative lumbar scoliosis is not clear, the most commonly implicated causes included osteoporosis [2, 17, 28], degenerative disc disease [2, 17, 28, 44], and vertebral body compression fracture [32]. Patients with degenerative lumbar scoliosis typically present with symptoms of lower back pain, radicular pain, and neurogenic claudication [5]. The natural history of untreated adult lumbar scoliosis is progression of the curve, and bracing cannot prevent progression of the curve in this skeletally mature patient [6, 34, 41]. Surgical indications in patients with degenerative lumbar scoliosis include failure of conservative treatment, neurological deficit, and progression of deformity [17, 18, 31, 42, 45, 54, 55]. Degenerative lumbar scoliosis is a triaxial deformity consisting of axial rotation in the vertical axis, lateral translation toward the convexity of the curve, and anterior translation in the sagittal axis [49], so surgery for degenerative lumbar scoliosis remains challenging, including improvement of the outcomes and radiographic parameters.

Newer advance surgical techniques in spinal fusion with transpedicular instrumentation have markedly improved the ability to correct spinal rigid deformity and surgical outcome [42]. Various methods of surgery for degenerative lumbar scoliosis are used, including decompression alone, decompression and posterior fusion with instrumentation, and combined anterior and posterior fusion with instrumentation [29]. The values of interbody support provided by posterior lumbar interbody fusion (PLIF) have been proven and have become increasingly popular and effective [25, 40, 60]. PLIF can restore disc height, achieve anterior vertebral support, increase lumbar lordosis, and reestablish spinal stability [40, 59]. Instrumented PLIF is an alternative circumferential fusion and is via a posterior approach. Pateder et al. [48] reported that when combined with extensive posterior release, posterior only approach (PLIF or TLIF) is just as effective in coronal and sagittal plane balance correction as combined anterior and posterior surgery for adult lumbar scoliosis.

Although instrumented PLIF has been becoming a popular and effective method for treating degenerative lumbar scoliosis, the clinical outcome is rarely reported. We retrospectively evaluated the clinical and radiographic outcomes in patients with degenerative lumbar scoliosis after instrumented PLIF.

Materials and methods

Inclusion and exclusion criteria

We analyzed patients with degenerative lumbar scoliosis ongoing posterior instrumented interbody cage fusion at the Kaohsiung Medical University Hospital from May 2004 to January 2007. Our surgical indications include failure of conservative treatment, neurological deficit, intractable pain, and progression of deformity. Inclusion criteria consisted of: (1) patient having been diagnosed of degenerative lumbar scoliosis—the definition of degenerative lumbar scoliosis being Cobb angle more than 10° [3]; (2) age >50 years at time of diagnosis; (3) refractory to medical treatment for 6 months; (4) corrected with posterior instrumented lumbar interbody fusion; and (5) follow-up >24 months. Exclusion criteria consisted of: (1) prior spinal trauma or fracture; (2) spinal malignancy; (3) spinal infection; and (4) adult idiopathic scoliosis. Sixty-one patients conformed to the above inclusion criteria. During the follow-period, three patients (3/61) were lost to follow-up.

Clinical characteristics

Clinical presentations

A total of 58 patient's clinical characteristics had been reviewed retrospectively. The average age of the patients was 68.9±8.5 years (range 51–83 years). There were 11 men and 47 women. All patients presented back pain, 45 patients presented radiculopathy, and 30 patients presented claudication.

Preoperative medical comorbidities

Twenty-nine of 58 (50%) patients had two or more medical comorbidities. Osteoporosis (38/58) and hypertension (34/58) were the most common comorbidities (Table 1). The commonly implicated causes in our series included osteoporosis (40/58, 69%), degenerative disc disease (58/58, 100%), and vertebral body compression fracture (8/58, 14%).

Table 1 Clinical characteristics of patients with degenerative lumbar scoliosis

Age (years)	68.9±8.5
Sex (M/F)	11:47
Comorbidity, *n* (%)	
Osteoporosis	38 (66)
Hypertension	34 (59)
Heart disease	13 (22)
Diabetes mellitus	6 (10)
Kidney disease	1 (2)
No. of levels decompressed (*n*)	3.9±0.9
No. of level fused (*n*)	2.4±0.7
No of level fixed (*n*)	5.3±1.7
Fusion extension to sacrum, *n* (%)	21 (36)
Op time (h)	7.2±1.7
Blood loss (mL)	1598±1006
Hospital stay (days)	17.2±7.7

Surgical techniques and perioperative status

Some of the central tenets to consider when treating adult patients with degenerative scoliosis are: (1) decompression of the neural elements for symptoms relief; (2) correction of sagittal balance as well as coronal and rotational deformity for spinal balance; (3) optimizing conditions for osteogenesis and fusion for stability of spine; and (4) prevention of the progression of curves [5]. Decompression, correction of the deformity, and stabilization are important surgical strategies in patients with degenerative lumbar scoliosis. First, decompression of the entire neural component in the stenois segments was performed by removing the hypertrophic ligmentum flavum, facet joint, and performing the lamainectomy and facetomy. Secondary, the extent of fixation and fusion were determined to the uppermost vertebrae and the lowermost vertebrae. Posterior pedicle screw instrumentation not only allows for correction of the deformity but also stabilization of the spine after the decompression.

Third, correction of deformity was performed. The shape of the rod was adjusted by the contour of screw placement and the angle of lordosis. The contouring rod was set in the convex side firstly. Modified bilateral apical derotation maneuver [7] was performed for the correction of scoliosis. A rod derotation maneuver and distraction on the concavity of the curve were used for spine realignment. After the first derotation, the pedicles were inserted again in the convey side. The second contouring rod was set in the convey side again. Correction of the deformity is done to as maximal a degree as possible. Finally, posterior lumbar interbody fusion was performed on all of our patients to stabilize the realigned spine.

Perioperative status included intraoperative blood loss, operative time, the number of levels fused and fixed, and the number of decompression level (Table 1).

Radiological examinations

Thoracolumbar anteriopposterior and lateral standing radiographs were reviewed preoperatively and postoperatively. The Cobb angle, L3 inclination, L4 inclination, lateral apical translation, and coronal balance were measured in the coronal axis. Nash–Moe grade and Nash–Moe degree were measured in the axial axis [46]. Lumbar lordosis, sacral inclination, and sagittal balance were measured in the sagittal axis [13]. The Cobb's angle of scoliosis in our patients was between 10° and 34°. Radiographic parameters were shown in Table 3.

Functional outcomes

Oswestry disability index (ODI), visual analog scale (VAS), and patient satisfaction were evaluated before surgery and last follow-up period. Patient satisfaction was classified as satisfied or dissatisfied according to self-reported outcomes at the last visit.

Postoperative complications

Postoperative complications were categorized both as early or late complications and minor or major complications (Table 2), including 39 (68%) early perioperative complications and 12 (28%) late complications. Early complications included pulmonary congestion (17%), ileus (36%), delirium (7%), and wound infection (10%). Late complications included adjacent segment disease (12%) and loosening of screws (14%). The average follow-up period was 38.7±11.0 months (range 24–59 months), with a minimum of 2 years' follow up.

Statistical analysis

Comparisons of the radiographic parameter of patients with degenerative lumbar scoliosis before surgery and the last follow-up period were made using paired *t* tests. The relationship between the difference of radiographic parameter and functional outcome was evaluated by the Pearson correlation analysis. Linear regression analysis was used to assess the factors related to the clinical outcomes and the radiographic outcomes. All statistical results were established significant if $p<0.05$. The analysis was performed with the SPSS 15.0 package software.

Results

The functional outcomes including ODI scores and VAS were significantly improved at the last visit (Table 3). The ODI was 28.1±8.0 before surgery and 12.2±8.8 at the last

Table 2 Postoperative complications in patients with degenerative lumbar scoliosis

Early complication, *n* (%)	
GI disturbances	21 (36)
Pulmonary congestion	10 (17)
Wound infection	6 (10)
Delirium	4 (7)
Urinary tract infection	2 (3)
Late complication, *n* (%)	
Screw loosening	8 (14)
Adjacent segment disease	7 (12)
Proximal	7 (12)
Distal	0
Reoperation	1 (2)
Follow-up period (months)	38.7±11.0

Table 3 Radiographic parameters and functional outcomes

Variable	Preoperative	Postoperative	p value
Coronary axis			
Cobb's angle (deg)	19.3±6.8	7.7±5.4	<0.001
Coronary balance (mm)	15.5±7.6	6.6±5.7	<0.001
Lateral apical translation (mm)	9.2±3.3	3.9±3.0	<0.001
Axial axis			
Nash–Moe grade	2.2±0.7	1.1±0.6	<0.001
Nash–Moe degree	27.6±10.4	11.3±8.0	<0.001
Sagittal axis			
Lordosis angle (deg)	30.0±13.7	29.0±9.5	0.459
Sacral inclination (deg)	26.1±9.5	25.2±8.2	0.305
Sagittal balance (mm)	−3.3±34.0	−4.2±27.2	0.800
Functional outcomes			
Oswestry disability index (ODI)	28.1±8.0	12.2±8.8	<0.001
Visual analog scale (VAS)	7.4±2.0	2.4±2.0	<0.001
Patient satisfaction		72%	

visit. The VAS was 7.4±2.0 before surgery and 2.4±2.0 at the last visit. Patient satisfaction was 72% at the last visit. Patient excellent satisfaction was 33% (19/58) and good satisfaction was 36% (20/58) at the last visit.

Although no significant correlation between preoperative radiographic parameters and pain (VAS), the preoperative lumbar lordosis angle was significantly related to the Oswestry disability index scores (p=0.021, Table 4). There was no significant correlation between postoperative radiographic parameters and pain (VAS, Table 5). ODI was significantly related to postoperative radiographic parameters including Cobb's angle (p<0.001), L4 inclination (p=0.011), coronal balance (p=0.007), lateral vertebral translation (p<0.001), Nash–Moe grade (p=0.033), Nash–Moe degree (p=0.025), and sagittal balance (p=0.041, Table 5).

Linear regression analysis was used to evaluate the correlation between ODI and difference in radiographic parameters and clinical parameters (Table 6). Female gender, number of levels fixed, Cobb' angle, coronal balance, lateral vertebral translation, Nash–Moe degree, and Nash–Moe grade significantly correlated with ODI in simple regression analysis. However, ODI was significantly related to female gender, number of levels fixed, coronal balance, lateral vertebral translation, and Nash–Moe degree in multiple regression analysis.

Linear regression analysis was also used to evaluate factors related to difference in the visual analog scale (Table 7). VAS was significantly related to Cobb' angle, coronal balance, lateral vertebral translation, and Nash–Moe degree; Nash–Moe grade demonstrated significant correlation in simple regression analysis. Only lateral vertebral translation demonstrated significant correlation in multiple regression analysis.

Discussion

Our studies demonstrated that instrumented PLIF in a patient with degenerative lumbar scoliosis can achieve high

Table 4 Correlation between preoperative radiographic parameters and functional outcomes

Variable	Oswestry disability index (p value)	Visual analog scale (p value)
Cobb's angle	0.316	0.689
L3 inclination	0.356	0.582
L4 inclination	0.220	0.337
Coronary balance	0.706	0.229
Lateral vertebral translation	0.243	0.247
Nash–Moe grade	0.886	0.834
Nash–Moe degree	0.745	0.979
Lordosis angle	0.021	0.269
Sacral inclination	0.282	0.694
Sagittal balance	0.060	0.328

Table 5 Correlation between postoperative radiographic parameters and functional outcomes

Variable	Oswestry disability index (*p* value)	Visual analog scale (*p* value)
Cobb's angle	<0.001	0.289
L3 inclination	0.052	0.533
L4 inclination	0.011	0.605
Coronary balance	0.007	0.698
Lateral vertebral translation	<0.001	0.243
Nash–Moe grade	0.033	0.756
Nash–Moe degree	0.025	0.876
Lordosis angle	0.385	0.378
Sacral inclination	0.187	0.384
Sagittal balance	0.041	0.016

rates of patient satisfaction and improvement in radiographic and clinical outcomes. The current study focuses on the VAS and ODI instruments outcomes because these were the most consistently used measures. Various clinical and radiographic factors were analyzed to understand the effect of instrumented PLIF for adult degenerative lumbar scoliosis.

Age and gender

An increasing number of elderly patients are undergoing operative treatment for degenerative lumbar disease. Surgery-related complications or mortality were increased in elderly patients [1, 9, 20, 60]. However, some authors have reported that posterior lumbar decompression and fusion can be safely performed in the elderly with a low complication rate [10] and that the age of patients was not a contraindication for surgery [42]. In our study, the age of patients has no significant relation to the clinical outcomes and complications.

Our study showed that female gender was a prognostic factor related to difference in Oswestry disability index scores in patients with degenerative lumbar scoliosis. Previous studies reported an influence of gender on back and leg visual analog scale, Oswestry disability index [33, 43], and patients' satisfaction [53] in patients undergoing spinal surgery. The reason of sex-related difference in spine surgery is still unknown. The reasons for gender differences

Table 6 Linear regression analysis between clinical parameters and difference in radiographic parameters

Variable	Simple linear regression analysis		Multiple linear regression analysis	
	$\beta\pm$SD	*p* value	$\beta\pm$SD	*p* value
Gender	8.40±3.09	0.009	6.54±3.24	0.043
Osteoporosis	0.68±2.79	0.808	1.80±2.67	0.503
No. of levels fused	−1.55±2.70	0.570	−1.45±2.81	0.607
No. of levels fixed	−7.71±2.37	0.002	−7.83±2.51	0.003
No. of levels decompressed	−0.45±2.79	0.873	1.34±2.71	0.622
Op time(min)	−4.10±2.58	0.117	−3.31±2.73	0.232
Blood loss (mL)	−2.13±2.57	0.412	−0.50±2.54	0.844
Difference in coronal axis				
Cobb's angle (deg)	1.00±0.18	<0.001	0.40±0.25	0.105
Coronary balance (mm)	0.90±0.17	<0.001	0.42±0.20	0.040
Lateral vertebral translation (mm)	11.87±2.13	<0.001	5.69±2.76	0.044
Difference in axial axis				
Nash–Moe grade	6.73±2.00	0.001	−3.31±2.76	0.235
Nash–Moe degree	0.80±0.14	<0.001	1.01±0.22	<0.001
Difference in sagittal axis				
Lordosis angle (deg)	−0.14±0.13	0.266	−0.11±0.18	0.540
Sacral inclination (deg)	NS	0.935	NS	0.831
Sagittal balance (mm)	NS	0.094	NS	0.235

Table 7 Linear regression analysis between difference in radiographic parameters and visual analog scale

Variable	Simple regression analysis		Multiple regression analysis	
	β±SD	p value	β±SD	p value
Gender	1.41±0.91	0.127	1.61±0.92	0.087
Osteoporosis	0.89±78	0.257	1.19±0.83	0.159
No. of levels fused	0.84±0.76	0.271	0.79±0.88	0.373
No. of levels fixed	−0.58±0.73	0.426	−0.70±0.74	0.352
No. of levels decompressed	0.49±0.79	0.536	0.64±0.80	0.430
Op time(min)	0.13±0.74	0.862	−0.14±0.85	0.868
Blood loss (mL)	0.31±0.73	0.678	0.37±0.76	0.638
Difference in coronal axis				
Cobb's angle (deg)	0.17±0.06	0.007	NS	0.768
Coronary balance (mm)	0.16±0.06	0.006	NS	0.384
Lateral vertebral translation (mm)	0.43±0.11	<0.001	0.40±0.16	0.018
Difference in axial axis				
Nash–Moe grade	1.21±0.60	0.047	0.31±0.96	0.747
Nash–Moe degree	0.11±0.05	0.022	NS	0.239
Difference in sagittal axis				
Lordosis angle (deg)	NS	0.398	NS	0.165
Sacral inclination (deg)	NS	0.181	0.12±0.07	0.077
Sagittal balance (mm)	NS	0.034	NS	0.267

in lumbar spine stenosis surgery are probably multifactor due to physiological, pharmacological, and psychological aspects [53]. Therefore, the gender of the patient must be taken into consideration as a crucial factor when performing the surgery in lumbar degenerative disease, especially in scoliosis.

Osteoporosis

Degenerative lumbar scoliosis is common in the elderly population and in particular in postmenopausal women as a consequence of osteoporosis. The incidence of osteoporosis increased with increasing age [11]. Osteoporosis is considered as a significant risk factor for spine instrumentation failure [15, 22, 30, 52]. So some authors attempt to find the fixation strategies for osteoporotic bone [5]. The strategies are targeted either toward taking advantage of the relatively stronger cortical bone [14] or toward augmenting the fixation of a pedicle screw within the existing trabecular bone [56]. In our cases, we routinely perform bone cement augmentation through the pedicle into the vertebral body.

Extension of the fixation and fusion

Determining the extent of the fixation and whether a fusion extends to the sacrum were important surgical strategies in patient with degenerative scoliosis. Several principles were proposed to decide the extent of fixation and fusion: (1) The instrumentation and fixation should not be confined in the deformity to prevent adjacent segment diseases [13, 55] and to prevent the progression of the scoliotic curvature [34, 57]. (2) The instrumentation and fixation should not end in the junction of thoracolumbar spine or sondyliosthesis to maintain sagittal balance or thoracic compensation [13, 34, 37, 55]. (3) Uppermost instrumented vertebrae were determined to restore the balance of spine and to correct the deformity. Most authors demonstrated that the most horizontal vertebrae should be chosen for upper instrumented vertebrae that could correct the deformity completely [34, 35]. In our cases, we choose the most horizontal upper endplate of adjacent two vertebrae as the upper instrumented vertebrae. Using this way to find the upper instrumented vertebrae, the extent of fixation should be shortened as possible under the spinal balance. (4) The level of rotatory subluxation, severe lateral listhesis, or spondylolisthesis must be fused to maintain the stability of the corrected spine. (5) Short segment fixation and fusion is appropriate for the patients with small scoliototic curvatures, without or mild spine imbalance [13, 34, 57]. (6) Long segment fixation and fusion is applied in patients with a larger scoliotic curvature or with severe spinal imbalance. In our study, the level of fixation was significantly related to the difference of functional outcomes between before and after instrumented posterior lumbar interbody cage fusion. Our study demonstrated that the number of level fixed can affect the patient outcome and satisfaction and that short segment fixation is preferred.

Fusion extension to sacrum

Fusion extent to the sacrum in patients with degenerative lumbar scoliosis still remains controversial. Long segment constructs with extension to the sacrum has a better radiographic correction [6], but fusion to the sacrum requires more procedures and more postoperative pseudoarthrodesis [23, 36, 38]. In contrast, arthrodesis at L5 can develop the subsequent progression of L5 S1 segment degeneration [6, 8, 24, 39]. The indications for fusion to the sacrum have been suggested as follows: (1) lumbosacral segment instability due to spondylolisthesis or previous instability [6, 24, 50]; (2) advanced or severe degeneration in the lumbosacral segment [6, 24, 50]; (3) scoliosis or deformity involving the lumbosacral region [6, 24, 50]; and (4) sagittal imbalance and lumbar hypolordosis before surgery [12]. In our study, 21 (21/58, 36%) patients had fusion extension to the sacrum in our series. Fusion extension to the sacrum was not a significant factor relating to the functional outcomes, but we must be meticulous in determining whether to fuse the sacrum in patients with degenerative lumbar scoliosis.

Radiographic correction and clinical outcome

The functional outcomes including ODI scores and VAS were significantly improved after surgery (Table 3). Our study demonstrated that the posterior interbody fusion with instrumentation improves not only in ODI but also in VAS associated with degenerative lumbar scoliosis in the elderly. Interestingly, there was no significant correlation between preoperative radiographic parameters and VAS; the preoperative lumbar lordosis angle was significantly related to ODI. The was no significant correlation between postoperative radiographic parameters and VAS. However, ODI was significantly related to postoperative radiographic parameters. This indicated that better radiographic corrections have better disability improvement (ODI), but not pain (VAS), associated with degenerative lumbar scoliosis in the elderly. VAS is a subjective pain estimator and is usually improved after surgical intervention. Our result demonstrated that VAS is slightly affected by radiographic parameters. ODI is a complex functional outcome estimator and is influenced by the paragraphic parameters and clinical parameters.

Scoliosis represents a complex three-dimensional rotational deformity that affects the spine in the coronal, sagittal, and axial planes. Some authors attempt to find the correction strategies in scoliosis. Correction strategies should be devised to normalize both sagittal balance and coronal and rotational deformity [5, 47]. Such a balanced spinal posture provides for decreased energy requirements with ambulation, limits pain and fatigue, improves cosmesis and patient satisfaction, and limits complications associated with unresolved deformities [35]. Most studies have demonstrated a correlation between radiographic correction and clinical improvement in patients with adult scoliosis [4, 16, 19, 26, 51], but restoration of spine balance is the important factor associated with a good clinical outcome [21, 26, 27] and pain relief [35, 51]. Restoring the balance of the spine in the coronal, axial, and sagittal axes was a more important factor relating to prognosis than other radiographic parameters in patients with degenerative lumbar scoliosis in surgical planning. Interestingly, the difference between preoperative and postoperative Cobb's angle was not found to have a significant correlation in our multivariate analysis in both ODI and VAS scores. This may have been because of the lower values of surgical correction of Cobb's angle of the patients included in this study. The association between Cobb's angle correction and ODI or VAS needs further investigation.

Conclusions

Based on the commonly reported clinical outcome measures, the VAS and ODI instruments, instrumented PLIF for adult degenerative lumbar scoliosis can achieve a high rate of patient satisfaction and improvement in radiographic and clinical outcomes at a minimum of 2 years' follow-up.

Conflicts of interest None.

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